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COMPOSITION AND ITS EFFECTS ON THE PRICE OF SOYBEANS AND SOYBEAN OIL[1]

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In discussing composition and its relation to the price of soybeans and soybean oil, I must refer briefly to the start of analytical work at the U. S. Regional Soybean Industrial Products Laboratory at Urbana, Illinois, in 1936. When that Laboratory was started, one of the four sections was an Analytical Section. The section had two main purposes in view.

The first was to determine in detail the composition of soybeans in the hope of finding "hidden values" in the constituents. At that time a complete analysis of soybeans had never been made and, in fact, a fairly large part of the mature soybean was of unknown composition. It seemed possible that in this unknown portion valuable constituents might be found that would enhance the value of the crop. The Laboratory at Urbana found that there was a surprising amount of sugar or sucrose in soybeans, averaging around 10 percent. Also work was undertaken and actively pursued on the sterols and phosphatides found in the soybean fraction. As you know, the soybean phosphatides have been extensively used, and sterols from soybeans now serve as a starting point for the synthesis of hormones.

The second purpose of the Analytical Section was to assist the agronomist and geneticist in their plant-breeding program. For this purpose it was necessary to find how composition was affected by variety, environment, and fertility level of the soil. With this information as background, continued analysis was needed to discover new varieties which had high oil and protein contents and to make sure that these varieties exceeded in these respects those in current production. The first 5 years' work on this second problem are summarized in Technical Bulletin 787 of the U. S. Department of Agriculture. On inspecting the reports in this bulletin on varieties studied for a 5-year period, you will be struck by the fact that most of them are no longer grown. This in itself is a tribute to the success of the agronomist and the geneticist, since the new varieties--Lincoln, Chief, Hawkeye, and the others now appearing--are a direct outgrowth of this breeding and testing program. The high oil content of the new varieties is not an accident. It was aimed for by the geneticist and confirmed by chemical analysis before these varieties were released for general use.

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I should like to emphasize the great importance of the oil content of soybeans in determining the value of the beans. Here are some figures, selected at random, showing the ratio of the price of 1 pound of oil to 1 pound of meal, covering certain years from 1932 to the present.

Year	Price ratio Oil/meal
1932	3.4
1937	4.1
1942	5.5
1947	5.7
1948 (May 14)	6.8

Note that the lowest this ratio has been is 3.4. This occurred not only in 1932 but also in 1939. At present, of course, with the extreme scarcity of oils and with the consequent high price of soybean oil, the ratio is extremely high. However, over this 16-year period, the oil has always been worth more than three times as much as the meal--pound for pound.

You will recall our experience during the war when it was necessary to obtain every possible pound of oil and fat because sources of foreign oils were cut off. To encourage farmers and utilize processing facilities fully, it was necessary for the Government, through the Commodity Credit Corporation, to assume complete responsibility for the soybean crop. Farmers were encouraged by a guaranteed price for soybeans based only on the commercial grading factors of moisture, foreign matter, damage, and the like. This price was paid by Commodity Credit Corporation who then sold the soybeans to processors at a price based primarily on the oil content of the beans. Differentials, of course, were allowed. These varied according to the type of processing employed (hydraulic, screw press, solvent). They were designed to give a reasonable profit to the processor and to allow extra profit as an incentive to efficient processing. Since the value of the beans depended so largely on oil content, extreme importance was attached to the accurate determination of oil content, and the official method of analysis for oil content was given a very severe test. This official method had been developed in previous years largely in research laboratories and more or less for academic use. It is a common experience that methods are not critically examined until they are used for trading purposes and involve premiums and discounts based on the analytical results. When Commodity Credit Corporation started basing prices on analytical oil determinations a great deal of trouble was at first encountered. Through cooperation and research, some of it conducted at the Northern Laboratory, it was possible to place this official analytical method for oil content of soybeans on a sound and reproducible basis so that results obtained by different laboratories were in agreement and truly reflected the yields which could be obtained in commercial process.

This official method, however, is tedious, requires more than 5 hours for completion, and the work must be done with specialized equipment and with considerable skill. Soybeans are no longer bought on an oil-content basis and undoubtedly the difficulty of analysis is a contributing reason for this. It would be extremely desirable to have an inexpensive, rapid, and accurate method for determining oil content, one which relatively unskilled operators could use. We have recognized the desirability of such a simple method for many years and have done a great deal of work on it. I wish I could report that we have been successful; instead I can only report some of the methods that have been tried and the reasons why we do not believe that they are successful.

One promising method, which was first developed for flaxseed, uses the difference in refractive index between soybean oil and a solvent as a measure of oil content. Briefly, the method consists of grinding the oilseed with a solvent, such as α-bromnaphthalene, which has a much higher index of refraction. A drop of the mixture of solvent and soybean oil is placed in a refractometer and the index read. Reference to a table then gives the amounts of soybean oil in the mixture and from this the oil content of the original soybeans can be calculated. Refractometers are relatively easy to operate and, of course, the reading may be taken in less than a minute. Unfortunately, the refractive index of soybean oil itself is not a fixed value but varies with the unsaturation or drying power of the oil. In fact, it may be used to measure the unsaturation and thus replace the iodine number determination. Because of this variation in refractive index, a correction, based on a measurement of the refractive index of the particular sample of soybean oil concerned, must be made. This means twice the work and although the method remains a fast one from the standpoint of total time from sampling to obtaining the final answer, it still is a tedious and exacting determination. To obtain sufficient accuracy the refractometer must be a special research model, usually costing more than $1,000, and it is rather fragile and delicate. The time required to make, for example, 100 oil determinations by the refractometric method would not be appreciably shorter than the time for 100 analyses by the present official chemical method. If the goal is a method sufficiently simple and fast for use by a country elevator on trucks of soybeans from the field, then we can hardly consider the refractometric method as satisfactory.

Another ingenious scheme depends on the difference in density between soybean oil and a solvent. An instrument called a "lipeometer" for determining the oil content in soybean oil meal has been on the market for a number of years. This instrument, really a special hydrometer, is used to measure the density of a special solvent which has been stirred with the ground sample. The solvent leaches out a fixed proportion of the oil present and the resulting change in density, when compared with the original solvent indicates the oil content of the oil meal. As I stated previously, this device was designed for oil meal which would not contain over 5 to 7 percent oil. It was reasonably accurate for this purpose and would distinguish, for example, between cake containing 4.0 and 4.5 percent oil. However, this difference of 0.5 percent is in reality one part in 8 or 9. If it is assumed that the same error will hold when the lipeometer is used on whole soybeans, then as much as 2.5 percent discrepancy in oil content would be possible; that is, values such as 16 percent and 18.5 percent would be regarded as being in agreement. It seems clear that this inaccuracy is much too great and that the lipeometer would be unsatisfactory in general use.

We have done some work at this Laboratory in attempting to modify and improve this principle of determining oil content. We feel that any successful method must necessarily be a physical one, and because density is a value which can be measured without elaborate apparatus we have attempted to refine and improve methods which depend on the difference in density between oil and a solvent. We discovered that volatile solvents, such as ether, chloroform, and carbon tetrachloride, are not satisfactory and hence have been working with bromoform which has a high boiling point and a very high density. In order to increase accuracy we have also reduced the amount of solvent used. Using 3 cc. of bromoform as solvent with a ground sample of 2 grams of soybeans, we have obtained values which agree fairly well with the chemical method. We found, however that the accuracy and reproducibility are not satisfactory. It is possible that further work will enable us to refine this method, but at present this method, like the others, is not suitable for accurate quantitative work.

In addition to the quantity of oil present in the soybeans, the quality or composition of the oil directly affects its use and value. The analysis of vegetable oils has been very difficult and for many years inaccurate values have been published. With the recent introduction of good physical instruments, such as ultraviolet spectrophotometers methods have been developed which measure directly the amounts of linoleic and linolenic acids in vegetable oils. You will recall that linoleic acid has two double bonds and linolenic acid has three double bonds, whereas oleic acid has only one double bond, and saturated acids have none. By treating vegetable oils with concentrated alkali dissolved in ethylene glycol, the double bonds can be made to migrate so that absorption of ultraviolet light results. This absorption can be used to determine the presence and amount of the original acids. This spectrophotometric method is the most accurate known method for determining fatty acid composition. The older method involves iodine number, thiocyanogen number, and amount of saturated fatty acids--three separate determinations. It is so long and tedious that there is difficulty finding chemists who are willing to conduct collaborative work when the old procedure is used.

Just as the fatty acid composition of oils is of interest chiefly to the drying-oil industry, the refining loss of an oil is of primary importance to processors of edible oils. This refining loss test, originally developed for cottonseed, has been modified through the years. A great amount of collaborative work has been carried out, and the test is quite well accepted by this trade. When it became desirable to adopt refining loss procedures for soybean oil, the cottonseed method was used. It was found that additional slight modifications were needed. These have been made and the method checked, and last fall it was felt that the method was satisfactory and could be used for trading purposes. Again, the "acid test" was applied to an analytical method. It is too soon yet to determine whether the method is completely satisfactory or needs further change. I might say that the Refining Committee of the American Oil Chemists' Society, in active collaboration with this Laboratory, has been testing an improved refining method which more closely simulates actual plant practice. A high-speed centrifuge is used to settle and compact the foots produced in refining. This so-called "centrifuge method" is now under collaborative test and gives promise of being a useful and valuable analytical method. The results are more accurate and the procedure is much faster than the present official oil refining test.

Color of the oil is another important characteristic. For both margarine and shortening uses, the refiners desire an oil which can be made almost colorless. The measurement of color has formerly been carried out by visual methods comparing a column of oil with tinted glasses. This has been rather unsatisfactory and has led to numerous disputes. During the past few years the Color Committee of the American Oil Chemists' Society has been studying the other more instrumental methods, and is proposing a spectrophotometer for use at selected wavelengths to measure the color of soybean oil. This method is not yet official but it gives every promise of being satisfactory and of being adopted in the near future.

One other factor affects the usefulness of soybean oil. This is sludge or tank settlings. The trading rules of the National Soybean Processors Association specifically mention sludge and provide penalties for excessive amounts of this material in a tank car of oil. Unfortunately, there is no chemical method for analyzing oil for sludge and no way of predicting when this material will appear or the amount that will show up. In recent years, especially with the advent of solvent extraction, more and more soybean oil has been degummed. This, of course almost completely removes the possibility of sludge formation. As long as a respectable price can be obtained for crude soybean gum on phosphatides, probably it will be profitable to degum the oil because a degummed oil is much more stable for shipment.

In emphasizing the important role played by chemical analysis in measuring the true value of soybeans and soybean products, I should like to emphasize especially the importance of controlling some of these factors discussed. You cannot control the oil content of soybeans because that is fixed both by the climate and the variety grown by the farmer. However for the sake of your own profits, it will certainly pay you to encourage farmers to grow only high oil content beans. The Experiment Stations and the Regional Soybean Laboratory will be very glad to furnish the names of high oil varieties and the areas to which they are adapted. Having purchased the beans, the processor can determine to a large extent the quality of the oil and meal which he produces. In the case of oil produced by the screw-press process, the small processor in particular must take care that this oil is cleaned up before shipment. It should be settled and filtered if trouble with sludge is to be avoided. I have heard complaints from refiners and buyers of oil that small mills, in particular, are most careless in this respect. The adjustment and maintenance of screw presses is also important in avoiding excessive amounts of settlings. I should like to caution you also on the difficulties in obtaining truly representative samples for analysis. Regardless of the method or the chemist, correct results cannot be obtained unless the sample is correctly taken and correctly subdivided. I have heard of cases in which two laboratories obtained different results on supposedly the same sample. An interchange of samples between laboratories showed, however, that there were really two distinct samples being analyzed. The chemist and his analyses have been and can be of great value in the profitable operation of soybean processing plants.